INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES
Vol 15, Issue 12, (2025) E-ISSN: 2222-6990

Evaluating the Usability of Digital Teaching Model: A Fuzzy Delphi Method

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DOI Link: http://dx.doi.org/10.6007/IJARBSS/v15-i12/27334
Published Date: 21 December 2025

Abstract
With the widespread application of digital technology in education, educational models are constantly evolving, and digital education has become the mainstream of educational development. This study, based on previous research, developed a digital teaching model based on the BOPPPS teaching model, which comprises three stages and nine sub-stages. In this study, the fuzzy Delphi method was used to conduct a questionnaire survey of 30 university mathematics experts to evaluate the usability of the developed digital teaching model's stages and sub-stages. The evaluation results show that the usability of all three stages and nine sub-stages was unanimously recognized by the experts. This study not only provides university mathematics teachers with a teaching model that is helpful for their teaching but also provides a method for evaluation using the fuzzy Delphi method.
Keywords: Digital Teaching Model, Fuzzy Delphi Method, Questionnaire, Mathematics

Introduction
Digitalization has opened up entirely new opportunities for education, completely disrupting traditional teaching and learning practices (Stelmah & Vasylyuk-Zaitseva, 2024). Therefore, the widespread use of digital technologies in education is crucial for building an innovative, inclusive and efficient education system. Such an education system can empower students both inside and outside the classroom, helping them to develop independent learning and active exploration, clarify career development goals, and realize their full potential (Chai, Hu, & Niu, 2023).

Research has shown that integrating digital technologies into the curriculum has become a necessary initiative that not only helps to create flexible educational environments (Haleem, Javaid, Qadri, & Suman, 2022), but also stimulates intellectual curiosity, enhances creativity, and actively engages students, which significantly improves the learning experience and outcomes. At the same time, digital technologies also enable personalized learning, providing students with more learning opportunities tailored to their needs (Schmid & Petko, 2019).

In today's mathematics classrooms, traditional lecture-based teaching still dominates, which is detrimental to students' personalized learning and the development of higher-order thinking skills such as problem-solving. Therefore, university mathematics classrooms urgently need to shift from the existing traditional lecture-based teaching model to a student-centered approach, moving away from the limitations of a teacher-centered approach (Robinson, Neergaard, Tanggaard, & Krueger, 2016). Against this backdrop, integrating digital technology into university mathematics classroom teaching is particularly necessary.

To this end, The researcher has developed a digital teaching model based on the BOPPPS teaching model, aiming to assist teachers in their teaching and enhance university students' problem-solving skills in mathematics.

Digital Teaching Model

This digital teaching model is based on the BOPPPS teaching model. Building upon this, and incorporating the TPACK theoretical framework and the characteristics of university mathematics courses, the activity was ultimately determined through an NGT workshop to consist of three stages and nine sub-stages.The three stages are pre-class, in-class, and post-class.

Pre-class Stage

To ensure students can better absorb classroom content and actively participate in interactions, the activities in the pre-class stage are crucial (Zhu, Ding, & Liu, 2025). In digital teaching model, the pre-class stage includes two sub-stages: "Bridge in I" and "Pre-assessment".

The "Bridge in I" sub-stage serves as the driving and preparatory step for teaching, aiming to stimulate students' learning motivation and provide prior knowledge. It is the starting point and key guiding factor for the entire teaching process.

The "Pre-assessment" sub-stage, conducted after the introduction, uses diagnostic assessments to understand students' existing knowledge and learning needs, providing a basis for subsequent teaching.

In-Class Stage

The in-class stage is the main stage of classroom teaching implementation and needs to be carefully designed to ensure that students gain the maximum benefit within a limited time (Zhu, Ding, & Liu, 2025). In digital teaching model, the in-class stage includes five sub-stages: "Bridge in II," "Objective Presentation," "Participatory Learning," "Post-test I," and "Summary I".

"Bridge in II" is the first sub-stage of the class, serving as a bridge between the preceding and following stages. Teachers can use this sub-stage to connect with the pre-class sub-stages while effectively conducting subsequent sub-stages. "Objective Presentation" clarifies learning objectives and task requirements, guiding students' learning direction. "Participatory Learning" is the core stage of the class, where students deepen and apply knowledge through group collaborative tasks and real-time interactive Q&A in a digital environment. The "Post-test I" sub-stage assesses immediate learning effectiveness through online exercises and oneminute questionnaires. "Summary I" is the final sub-stage of the class. It primarily summarizes the content of the class, organizes the knowledge, helps students grasp key points, and provides feedback and summary on students' learning progress (Zhu, Yao, Zhang, & Zhan, 2024).

Post-Class Stage

The post-class stage is for reinforcing learning, answering questions, promoting communication, and reflecting on teaching (Wang, 2025). In digital teaching model activities, the post-class stage includes "Pre-test II" and "Summary II".

In the "Post-test II" sub-stage, teachers can publish Post-class Assignments through the Chaoxing Learning Platform. The assignments include objective questions such as multiple choice and true/false questions, as well as subjective questions such as calculation and application questions, to achieve a comprehensive assessment of students. The "Summary II" sub-stage reflects the final output of the teaching loop, completing the internalization of knowledge and the sublimation of experience.

Methodology

Research Sample

This study used the Fuzzy Delphi Method to evaluate the usability of the developed digital teaching model. The sample for the Fuzzy Delphi Method consisted of experts in the field (Kamal, Salleh, Zulkifli, Jamil, & Othman, 2023). To obtain more comprehensive and reliable results, the sample size for the Fuzzy Delphi Method should be 15-35 people (Jamil, Idris, Aris, Razalli, & Md, 2024). Therefore, this study selected 30 experts who work in the field of university mathematics teaching to respond.

*Research Instrumen***t**

This study used a Fuzzy Delphi questionnaire to evaluate the usability of the three stages and nine sub-stages of the developed digital teaching model. The researcher chose the fuzzy Delphi method because it is a systematic method with advantages such as saving questionnaire survey time and costs, reducing the total number of surveys, and increasing the questionnaire response rate. This method does not discard the respondents' original opinions and reflects their true responses, thus providing valid and reliable conclusions (Zha, 2025).The questionnaire used a seven-point Likert scale.

Data Analysis

The Fuzzy Delphi Method was implemented in the following steps:

i) Determine the language scale

The linguistic scale is a Richter scale with fuzzy numbers added, i.e., a fuzzy value conversion scale. The triangular fuzzy numbers are first obtained by arranging the values of m_1 、 m_2 and m_3 . The value of m_1 represents the minimum value, then the value of m_2 represents the reasonable value, and the value of m_3 represents the maximum value (Ismail et al., 2019) as shown in Figure 1 below.

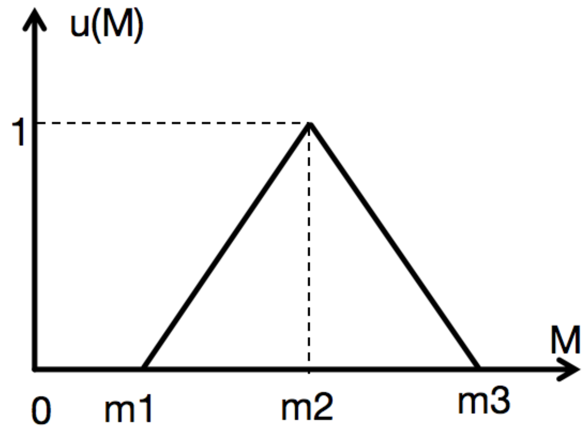

*Figure*1 Triangular Fuzzy Numbers

Triangular fuzzy numbers are used to generate fuzzy value conversion tables to convert linguistic variables to fuzzy numbers (Ismail et al., 2019).
Table1 shows the seven-point Richter scale values with fuzzy values conversion table (Ismail et al., 2019).

Table1
The seven-point Richter scale values with fuzzy values conversion table

Linguistic scale	Fuzzy Scale			Likert Scale
	m_1	m_2	m_3	
Strongly disagree	0.0	0.0	0.1	1
Totally disagree	0.0	0.1	0.3	2
Disagree	0.1	0.3	0.5	3
Not sure	0.3	0.5	0.7	4
Agree	0.5	0.7	0.9	5
Totally agree	0.7	0.9	1.0	6
Strongly agree	0.9	1.0	1.0	7

ii) Calculation of average fuzzy value
The teacher is given three fuzzy values for each item, then the average of the three fuzzy values for each item can be derived (Zha, 2025), which is calculated as follows:

$$M_i = \frac{\sum_{j=1}^{n} m_{ij}}{n} \quad (\mathrm{i} = 1,2,3) \qquad (1)$$

iii) Calculate the threshold d

Based on the formula $d(\overline{M}, \overline{m}) = \sqrt{\frac{1}{3}[(M_1 - m_1)^2 + (M_2 - m_2)^2 + (M_3 - m_3)^2]}$ (2)

The d-value is calculated (d-value indicates the distance between the average of the three fuzzy values for each item in the questionnaire and each expert's rating of the fuzzy number). The mean of the threshold (d-value) is calculated for each item, and the mean of the d-value is less than or equal to 0.2, which indicate that a consensus might be reached. d-value exceeding 0.2 indicated that the experts fail to reach a consensus, and depending on the situation it might be necessary to proceed to the second round of research (Chen, 2000).

In addition to examining whether the d-value is less than or equal to 0.2, it is necessary to determine the number of expert ratings for each item as a proportion of the total number of experts, Percentage of expert consensus,with items retained if the proportion exceeds 75% (Murry Jr & Hammons, 1995).

iv) Determination of α cut-off level
α cut-off is a method commonly used in fuzzy set theory to extract the level of fuzzy numbers in different intervals at the same confidence level for defuzzification. When αtakes different values, fuzzy intervals at different confidence levels can be obtained for analyzing the degree of expert consensus (Hsu & Sandford, 2007). According to previous studies, the α cut-off may be set to 0.5,as the range of fuzzy numbers lies between 0 and 1 (Bodjanova, 2006).

v) Defuzzification process
The process of defuzzification of a triangular fuzzy number involves converting it into a definite value. This is usually done by calculating the mean or median value of the fuzzy number. Hereafter referred to as the fuzzy score (DV). The fuzzy score (DV) for each questionnaire item is calculated using the following formula:

$$DV = \frac{m_1 + m_2 + m_3}{3} \quad (3)$$

where m_1 、 m_2 and m_3 are the average of the three fuzzy numbers in each item.If the derived DV value is less than the cut-off level of 0.5, it indicates that the experts unanimously agree that the item should be rejected. Conversely, if the derived DV value is greater than or equal to the cut-off level of 0.5, it indicates that the experts unanimously agree that the item should be accepted.

Based on the above analysis, (1) the threshold (d) must not exceed 0.2; (2) the percentage of expert consensus must be greater than or equal to 75%; and (3) the α cut-off score must be greater than or equal to 0.5. Items that meet the above three criteria are retained, items that meet only one of the criteria are discarded, and the remaining items go into the next round of expert research scoring until the expert scores no longer fluctuate significantly. This method ultimately determines the availability of the stages and sub-stages of the developed digital teaching model.

Research Result
This section contains 10 items, using a seven-point Likert scale to assess the usability of the digital teaching model at both the stage and sub-stage levels. See Table 2 for the specific items.

Table 2
The Usability of Digital Teaching Model at Stages and Sub-stages

No.	**Item**	**No.**	**Item**
1	Before class-During class-After class	**6**	Participatory Learning
2	Bridge in I	**7**	Post-test I
3	Pre-test	**8**	Summary I
4	Bridge in II	**9**	Post-test II
5	Objectives Presentation	**10**	Summary II

The researcher calculated the average threshold, fuzzy score, expert consensus, and ranking for each item. See Table 3.

Table 3
Average Threshold, Fuzzy Score, Expert Consensus, and Ranking for Usability in Activity Stages and Sub-stages of the Digital Teaching Model

No.	The average value of d each item	% Expert consensus on each item	Fuzzy score	Expert agreement	Rank
1	0.089	80	0.766	Accept	10
2	0.068	96.7	0.861	Accept	4
3	0.153	83.3	0.797	Accept	8
4	0.092	96.7	0.836	Accept	5
5	0.018	100	0.868	Accept	3
6	0.054	93.3	0.939	Accept	1
7	0.118	96.7	0.811	Accept	6
8	0.076	96.7	0.877	Accept	2
9	0.142	90	0.799	Accept	7
10	0.135	90	0.787	Accept	9

After analysis using the Fuzzy Delphi Method (FDM), all 10 items met the expert consensus criteria (threshold d ≤ 0.2, Expert Agreement ≥ 75%, fuzzy score ≥ 0.5), indicating that all items were considered acceptable and had good usability by experts.

The results show high expert consistency, with the percentage of expert consensus for all items ranging from 80% to 100%, demonstrating a consensus among experts on each item. Regarding fuzzy scores, all items scored above the cutoff value (0.5), indicating good usability. The average threshold d value for each item ranged from 0.018 to 0.153, all less than 0.2, indicating minimal dispersion in expert scores.

In summary, all 10 items in this phase were confirmed to have high usability and expert consensus. In particular, the Participatory Learning, Summary I, and Objectives Presentation items performed best in terms of fuzzy scoring and consistency, and can be regarded as core key sub-phases. In actual teaching, teachers should focus on implementing these sub-phases, which can help teachers improve teaching quality and promote the development of students' problem-solving skills.

Conclusion

The study results show that the usability of both the stages and sub-stages of the developed digital teaching model was highly recognized by experts. This indicates that the digital teaching model are highly usable for use in university mathematics classrooms. These findings will facilitate the further implementation of the developed digital teaching model in university mathematics classrooms. Furthermore, they will help university mathematics teachers further utilize digital technology in their teaching, thereby improving teaching quality and student learning outcomes， and thus it holds significant practical implications.

In addition, this study innovatively introduces the Fuzzy Delphi Method into the usability evaluation system of digital teaching model. Leveraging the professional opinions of 30 experts in the field of university mathematics based on a 7-point Likert scale, it constructs a quantitative evaluation framework of "teaching model adaptability + expert consensus verification." This fills the methodological gap in the existing evaluation of digital teaching model regarding the transformation from qualitative experience to quantitative standards, providing a replicable methodological reference for the usability evaluation of complex teaching models in the field of educational technology.

In terms of theoretical research, this study reconstructs the model by integrating digital teaching characteristics on the basis of the classic BOPPPS teaching model. Empirical research has confirmed that all reconstructed sub-stages meet the consensus criteria of the Fuzzy Delphi Method. This achievement enriches the theoretical connotation of the BOPPPS teaching model in the context of digital transformation and provides a theoretical basis and practical reference for the development and verification of similar teaching models in the future.

References

Bodjanova, S. (2006). Median alpha-levels of a fuzzy number. *Fuzzy sets and Systems, 157*(7), 879-891.https://doi.org/10.1016/j.fss.2005.10.015

Chai, H., Hu, T., & Niu, G. (2023). How proactive personality promotes online learning performance? Mediating role of multidimensional learning engagement. *Education and Information Technologies, 28*, 4795–4817.

Chen, C. T. (2000). Extensions of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy sets and systems, 114*(1), 1-9.

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers, 3*, 275-285. https://doi.org/10.1016/j.susoc.2022.05.004

Hsu, C. C., & Sandford, B. A. (2007). The Delphi technique: making sense of consensus. *Practical assessment, research, and evaluation, 12*(1).https://doi.org/10.7275/pdz9-th90

Ismail, N. K., Mohamed, S., & Hamzah, M. I. (2019). The application of the fuzzy Delphi technique to the required aspect of parental involvement in the effort to inculcate positive attitude among preschool children. *Creative Education, 10*(12), 2907-2921.https://doi.org/10.4236/ce.2019.1012216

Jamil, M. R. M., Idris, N., Aris, N. M., Razalli, A. R., & Md, M. M. (2024). Crafting a blueprint for enhancing emotional well-being in special education post-pandemic: A fuzzy Delphi approach.

Kamal, M. F. M., Salleh, R. M., Zulkifli, R. M., Jamil, M. R. M., & Othman, H. (2023). Identification of cooperative learning component in designing lesson plan for building drawing subject in vocational colleges. *Journal of Technical Education and Training, 15*(1), 20-27.https://doi.org/10.30880/jtet.2023.15.01.003

Robinson, S., Neergaard, H., Tanggaard, L., & Krueger, N. F. (2016). New horizons in entrepreneurship education: from teacher-led to student-centered learning. *Education+ training, 58*(7/8), 661-683.https://doi.org/10.1108/ET-03-2016-0048

Schmid, R., & Petko, D. (2019). Does the use of educational technology in personalized learning environments correlate with self-reported digital skills and beliefs of secondary-school students? *Computers & Education, 136*, 75-86. https://doi.org/10.1016/j.compedu.2019.03.006

Stelmah, N., & Vasylyuk-Zaitseva, S. (2024). Digital transformation in education: Using technologies for enhancement of efficiency of teaching.: https://doi.org/10.57125/FED.2024.03.25.10

Zha, J. (2025). Exploring the integration of student-centered evaluation strategies into flipped classrooms in vocational college English teaching: A study based on the fuzzy Delphi method. *Journal of Wuhan Vocational and Technical College, 24*(1), 42-50. https://doi.org/10.19899/j.cnki.42-1669/Z.2025.01.007

Zhu, L., Yao, A., Zhang, C., & Zhan, Y. (2024). Application of a 5G-enabled smart classroom based on the BOPPPS model in clinical nursing education. Journal of Nursing*, 39*(5), 14–17.

Zhu, M., Ding, Y., & Liu, R. (2025). Exploration of a blended teaching model for the course "Principles and Applications of Big Data Technology" under the OBE concept. *Journal of Jiamusi University (Social Science Edition), 43*(10), 146–149.